Expectations and the Rate of Inflation

Iván Werning  MIT
Expectations → Inflation?

Q: Passthrough in standard models?
Expectations → Inflation?

- Widespread belief… YES!
  - managing expectations is key…
  - … expectations cause inflation…
  - … near one-for-one

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• Recent events…
  2021: expectations anchored, inflation will be small & transitory
  2022: tighten monetary policy to lower expectations

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• What do we know?…
  • Evidence: difficult, but some promising recent work
  • Theories: Calvo gives 1-to-1? others?…

Q: Passthrough in standard models?
This Paper

• Standard pricing models…
  ▪ time-dependent: Calvo, Taylor, general
  ▪ state-dependent “menu costs”

• Solve: Optimal Pricing + Aggregation

• Important…
  • allow for arbitrary expectations $\pi^e$
  • “temporary equilibrium” (learning literature)

• Passthrough: $\pi = \phi \pi^e + \text{other stuff}$

• Full Phillips Curve $\pi_t = \sum \phi_s \pi^e_{t+s} + \sum \phi_s \pi_{t+s} + \cdots$
expectations of inflation → price/wage setters → inflation
Expectation Formation

expectations of inflation → price/wage setters → inflation
Expectation Formation

- Expectations of inflation
- Expectations of output
- Expectations etc.

→ Price/wage setters

→ Consumption

→ Policy

→ Inflation

→ Output

→ Etc.
Expectation Formation

Paper Focus
Contributions

- expectations of inflation
- price/wage setters
- inflation
Contributions

- Expectations of inflation
- Price/wage setters
- Inflation

Simple Passthrough Metric
Contributions

expectations of inflation → price/wage setters → inflation

Explore Wide Range of Pricing Model
Simple Passthrough Metric
Contributions

- **Expectations of Inflation**
- **Price/Wage Setters**
- **Inflation**

**Short vs Long Run Expectations?**
**Explore Wide Range of Pricing Model**
**Simple Passthrough Metric**
Results #1

- Passthrough: *wide range*…
  - dependent on pricing model
  - not \(\sim 1\), potentially low

- Calvo: in theory \(\phi \to 0\) if prices very sticky…
  … in practice \(\phi \approx 1\)

- Taylor: \(\phi = \frac{1}{2}\)

- **Sufficient statistics** for general time-dependent…

\[
\phi = \frac{\text{duration of ongoing}}{\text{duration of completed}}
\]
Results #2

• Q: How low can we go?  A: $\phi^* = \frac{1}{2}$ Taylor!

• Q: How high?  A: any $\phi > 1$!

• Full Phillips Curve…

$$\pi_t = \sum_{s=0}^{\infty} \phi_s \pi_{t+s} + \sum_{s=-1}^{-\infty} \phi_s \pi_{t+s} + \cdots$$

• coefficients $\phi_s$ fall and zero outside rigidity

• long-run Phillips curve vertical: $\sum_{s=-\infty}^{\infty} \phi_s = 1$
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Results #3

• Basic state dependent “menu cost”...
  • passthrough extreme, very sensitive to specification...
• Sheshinksi-Weiss: $\phi < 0$
• Golosov-Lucas: $\phi > 1$

• Extensions...
  • Short run: fixed frequency $\phi < 1/2$
  • Menu costs for changing bands: $\phi = 0$
Related Literature

- **Empirical Expectations**: Coibion-Gorodnichenko-Ropele, Coibion-Gorodnichenko-Kumar, Rosolia

- **Non-Rational Expectations**: Preston, Garcia-Woodford, Farhi-Werning

- **Phillips Curve**: Whelan, Sheedy, Wang-Werning, Auclert-Rigato—Rognlie-Straub

- **Menu Costs**: Sheshinski-Weiss, Alvarez-Beraja-Gonzalez-Neumeyer
Overview

1. Calvo \( \phi = 1 \)
2. Taylor \( \phi = \frac{1}{2} \)
3. General Time-Dependent \( \phi = \text{ongoing/completed} \)
4. Basic State Dependent
5. Extension to State Dependent
Calvo

• Goal…
  • passthrough from inflation expectation to inflation
  • holding everything else fixed, real marginal costs, demand, interest rates, etc.

• Wrong answer: use NK Phillips curve $\phi = \beta \approx 1$

$$\pi_t = \kappa x_t + \beta E_t \pi_{t+1}$$
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$\phi = 0?$
Calvo

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\]

Rational Expectation  $\rightarrow$ inflation & real marginal costs tied up

Need to separate them!
\[ p_t^* = \mu + (1 - \beta \lambda) \sum_{s=0}^{\infty} (\beta \lambda)^s (P_{t+s}^e + m c_{t+s}^e) \]
Calvo

\[ p_t^* - P_{t-1} = (1 - \beta \lambda) \sum_{s=0}^{\infty} (\beta \lambda)^s (P_{t+s}^e - P_{t-1}) + a_t \]
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\[ \pi_t = (1 - \lambda)(p_t^* - P_{t-1}) \]
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\[ P_{t+s} - P_{t-1} = \pi^e (1 + s) \]

Simple Inflation Expectation
Calvo

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Simple Inflation Expectation

\[ p_t^* - P_{t-1} = \frac{1}{1 - \beta \lambda} \pi^e + a_t \]
Calvo

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Simple Inflation Expectation

\[ p_t^* - P_{t-1} = \frac{1}{1 - \beta \lambda} \pi^e + a_t \]

\[ \pi_t = \phi \pi^e + (1 - \lambda) a_t \]

\[ \phi = \frac{1 - \lambda}{1 - \beta \lambda} \]
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- \( \phi \to 0 \) as \( \lambda \to 1 \) for any \( \beta \)
$\phi = \frac{1 - \lambda}{1 - \beta \lambda}$

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- $\phi \to 1$ as $\lambda \to 0$ or $\beta \to 1$
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In theory \(\phi \in (0,1)\)

- Continuous-time \(\phi = \frac{1}{\rho/\delta + 1}\)

\(\rho \leq 0.05\) \(\delta \geq 1\) (one year stickiness)
Calvo

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\( \rho \leq 0.05 \quad \delta \geq 1 \) (one year stickiness) \( \phi \geq 0.95 \)
Calvo

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- Continuous-time \( \phi = \frac{1}{\rho/\delta + 1} \)

\( \rho \leq 0.05 \quad \delta \geq 1 \) (one year stickiness) \( \phi \geq 0.95 \)

In practice \( \phi \approx 1 \)
Overview

1. Calvo $\phi = 1$

2. Taylor $\phi = \frac{1}{2}$

3. General Time-Dependent $\phi = \text{ongoing/completed}$

4. Basic State Dependent

5. Extension to State Dependent
Taylor $\beta \rightarrow 1$

- Fixed prices for N periods…
- … staggered across goods

\[ p_t^* - P_t = \frac{1}{N} \sum_{s=0}^{N-1} P_{t+s}^e + a_t \]

\[ \pi_t = \frac{1}{N} (p_t^* - P_{t-1}) \]
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\[ \pi_t = \phi \pi^e + \frac{1}{N} a_t \]

\[ \phi = \frac{1}{2} + \frac{1}{N} \]
Taylor $\beta \rightarrow 1$

- Fixed prices for $N$ periods...
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\[ \phi = \frac{1}{2} + \frac{1}{N} \]

\[ \phi \approx \frac{1}{2} \]
Taylor $\beta \rightarrow 1$

- Fixed prices for $N$ periods…
- …staggered across goods

\[
\begin{align*}
    p_t^* - P_t &= \frac{1}{N} \sum_{s=0}^{N-1} P_{t+s}^e + a_t \\
    \pi_t &= \frac{1}{N} (p_t^* - P_{t-1})
\end{align*}
\]

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\end{align*}
\]

Intuition: Overshooting

$Pt^*$
Intuition: Overshooting
Intuition: Overshooting

\[ P_t \]

\[ p_t^* \]

Calvo short spell
Intuition: Overshooting

### Graph

- **$p_t^*$**
- **$P_t$**
- **Calvo long spell**

**Legend:**
- Orange line represents a long spell.
Intuition: Overshooting

\[ P_t \]

\[ p_t^* \]

Calvo long spell

tail risk
Intuition: Overshooting

\[ P_t \]

long spell

\[ p_t^* \]
Intuition: Overshooting

$Pt^*$

bigger overshoot

long spell
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General Time Dependent Model

- General profit function: complementarities, markups, real marginal costs etc.
- General hazard rate $\{h_s\}$ for $s = 0, 1, \ldots$
- Two probability densities…
  - completed spells $f_s$ (fraction of spells ending at s)
  - ongoing spells $\omega_s$ (fraction time spent at s)
- Accounting…
General Time Dependent Model

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- Accounting...

\[
\begin{align*}
\bar{h} &= \sum_{s=0}^{\infty} \omega_s h_s = \frac{1}{\bar{d}} \\
\bar{d} &= \sum_{s=0}^{\infty} f_s s \\
\hat{d} &= \sum_{s=0}^{\infty} \omega_s s
\end{align*}
\]

frequency \hspace{2cm} completed duration \hspace{2cm} ongoing duration
General Time Dependent Model $\beta \to 1$

$$\phi = \bar{h} \sum_{s=0}^{\infty} \omega_s (1 + s) = \frac{\sum_{s=0}^{\infty} \omega_s (1 + s)}{\sum_{s=0}^{\infty} f_s (1 + s)} = \frac{\hat{d}}{\bar{d}}$$
General Time Dependent Model $\beta \rightarrow 1$

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- Calvo $\tilde{d} = \hat{d}$
- Taylor $\hat{d} = \frac{1}{2} \tilde{d}$
General Time Dependent Model $\beta \rightarrow 1$

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- Calvo $\bar{d} = \hat{d}$  
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  $\uparrow$ frequency  $\downarrow$ overshoot
General Time Dependent Model $\beta \rightarrow 1$

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- Heterogeneity

$$\phi = \int \frac{\hat{d}(i)}{\bar{d}(i)} \, di$$

- Ongoing
- Completed
General Time Dependent Model $\beta \rightarrow 1$

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\[
\phi = \int \frac{\hat{d}(i)}{\bar{d}(i)} \, di \neq \int \frac{1}{\bar{d}(i)} \, di \cdot \int \hat{d}(i) \, di
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General Time Dependent Model $\beta \rightarrow 1$

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$$
\phi = \int \frac{\hat{d}(i)}{\bar{d}(i)} di \neq \int \frac{1}{\bar{d}(i)} di \cdot \int \hat{d}(i) di \neq \frac{\int \hat{d}(i) di}{\int \bar{d}(i) di}
$$
Phillips Curve

Proposition.

\[ \pi_t = \sum_{s=0}^{\infty} \phi_s \pi_{t+s}^e + \sum_{s=-1}^{-\infty} \phi_s \pi_{t+s} + a_t \]

\( \phi_s \) decreasing \( \phi_s \rightarrow \infty \rightarrow 0 \)

Long-Run Phillips Curve Vertical \( \sum_{s=-\infty}^{\infty} \phi_s = 1 \)
Phillips Curve

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• Intuition: early inflation affects current and future periods effects zero outside rigidity!
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• Sheedy (2010) Rational Expectations: \( \hat{\phi}_1 = 1 \) (as NK) and \( \hat{\phi}_s < 0 \)
Overview

1. Calvo $\phi = 1$
2. Taylor $\phi = \frac{1}{2}$
3. General Time-Dependent $\phi = \text{ongoing/completed}$
4. State Dependent
5. State Dependent with Frictions
State Dependent “Menu Costs”
State Dependent “Menu Costs”

- Steady State: Sheshinski-Weiss (1977)
  - menu cost $c$ of changing price
  - constant inflation $\pi$
  - bands for $x = p - P$
State Dependent “Menu Costs”

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  - bands for $x = p - P$

- Out of Steady Steady…
  - start at steady state $\pi_0$
  - shock expectations: $\pi^e$ rises
  - what do firms do on in short run?
State Dependent “Menu Costs”
State Dependent “Menu Costs”

- $t < 0$ uniform density over interval $[x, x^*]$
State Dependent “Menu Costs”

- $t < 0$ uniform density over interval $[x, x^*]$
- $t = 0$ widen bands! …
State Dependent “Menu Costs”

• $t < 0$ uniform density over interval $[x, x^*]$

• $t = 0$ widen bands! …

No Price Changes!

$\pi = 0$
State Dependent “Menu Costs”

- $t < 0$ uniform density over interval $[x, x^*]$
- $t = 0$ widen bands! ...

**Proposition. (Sheshinksi-Weiss)**

a. ↑ $\pi^e$  \hspace{1cm} $\pi = 0$

b. ↓ $\pi^e$  \hspace{1cm} $P_+ > P_-$

- No Price Changes!  
  \[ \pi = 0 \]

\[ \text{“} \phi = -\infty \text{”} \]
Overview

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5. Extension to State Dependent
State Dependent

- Extreme shifts in frequency of price changes
- Realistic? Maybe not…
  - Firms *really* stop changing prices? Unlikely!
- Two ideas…
  - short-run fixed frequency
  - fixed costs of changing bands
Short Run Frictions (Extension #1)
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• Idea…
  • devoted resources for changing prices
  • fixed in very short run (or adjustment costs)…
  • … but not in medium run
Short Run Frictions (Extension #1)

• Idea…
  • devoted resources for changing prices
  • fixed in very short run (or adjustment costs)…
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• Optimal…
  • firm keeps changing lowest prices
  • how much upper bound?
\[ \pi = \bar{h}(x^* - x) \]
Proposition. Sheshinksi-Weiss with Short Run Friction

$\phi \in (0, \frac{1}{2})$

$\pi = \bar{h}(x^* - x)$

$x$  $x^*$  $x^*$
**Proposition.** Sheshinksi-Weiss with Short Run Friction

\[ \pi = \bar{h}(x^* - x) \]

\( \phi \in (0, \frac{1}{2}) \)

- Intuition…
  - adjust reset price up, **but less than Taylor!**
  - firm anticipates adjusting reset price more quickly
Intuition: Modern Times (1936)
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Cost of Changing Pricing Policies
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- Menu costs?...
  - cost of menus/stickers
  - manager time
- ... but changing pricing also incurs manager time!

- Cost $c_B$ of changing bands e.g. $c_B/c \in [1,10]$
- Used old policies if $mc^2$
Cost of Changing Pricing Policies

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$$V(x(\pi_0), x^*(\pi_0), \pi^e) \geq V^*(\pi^e) + c_B$$
Proposition.

a. inaction region: $\pi^e \in [\pi, \bar{\pi}] \implies \phi = 0$

b. $\bar{\pi}$ increasing in $c_B$ and

$$\frac{\partial}{\partial c_B} \bar{\pi} \big|_{c_b=0} = \infty$$
Proposition.

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Golosov-Lucas

- Adds idiosyncratic shocks… (follow Alvarez et al)
  - extreme: $\phi = \infty$
  - move both bands up!
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• Short run friction…
  • mitigates effect
  • less if constraint on total adjustments \( h_+ + h_- \)
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  - less if constraint on total adjustments $h_+ + h_-$

- $mc^2$ even stronger mitigation (care less as much about inflation)

- Generation 3.0 menu cost models? (N goods, free price changes, etc.)
Conclusions

• Results…
  - time dependent: lower passthrough than 1, sufficient statistics, short-run expectations …
  - state dependent: extreme, added frictions
Conclusions

• Results…
  • time dependent: lower passthrough than 1, sufficient statistics, short-run expectations …
  • state dependent: extreme, added frictions

• Other benefits?…
  • inspect mechanisms: economic intuition (overshoot)
  • look at other shocks in menu costs than just monetary policy
  • suggests extensions of menu cost models
  • spillovers to learning: inspect feedback (understood to be important)
  • spillover to empirics: measure overshoot, sufficient stats, …
Inattention and Behavioral Agents

• Other options to affect response of inflation
  • agents do not revise expectations
  • or just do not act on them:
  • Examples: rational inattention, imperfect information, Hybrid NK Phillips curve